



EDGEWOOD

CHEMICAL BIOLOGICAL CENTER

U.S. ARMY SOLDIER AND BIOLOGICAL CHEMICAL COMMAND

ECBC-TR-008

DOMESTIC PREPAREDNESS PROGRAM: LIQUID SULFUR MUSTARD AND
SARIN CHALLENGE/VAPOR PENETRATION SWATCH TESTING
OF MARMAC COMMANDER BRIGADE ENSEMBLE
STYLE 10000F91

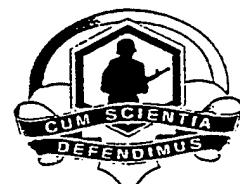
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Robert S. Lindsay
Terri L. Longworth
Marcia A. Johnson

ENGINEERING DIRECTORATE

February 1999

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Aberdeen Proving Ground, MD 21010-5424

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Preface

The work described in this report was authorized under the Expert Assistance (Personal Protective Equipment Evaluation) Program for the U. S. Army Edgewood Research, Development and Engineering Center (ERDEC)* Program Director for Domestic Preparedness. The work was started in February 1998 and completed in March 1998.

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DOMESTIC PREPAREDNESS PROGRAM: LIQUID SULFUR MUSTARD AND
SARIN CHALLENGE/VAPOR PENETRATION SWATCH TESTING
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STYLE 10000F91

1. INTRODUCTION

Under the Domestic Preparedness (DP) Expert Assistance (Personal Protective Equipment (PPE) Evaluation) Program, the U. S. Army Edgewood Research, Development and Engineering Center (ERDEC)* was tasked to perform testing of swatches taken from commercially-available Level A suits currently being used by emergency responders from cities involved in this program. The testing was performed by the Design Evaluation Group, Surety Team, Methodology, Instrumentation and Test Office, Engineering Directorate. The test procedure was jointly developed and agreed upon by ERDEC and the U. S. Army Natick, Research, Development and Engineering Center (NRDEC) (written communication, M. Chin, NRDEC, 1 May 97).

2. MATERIALS AND METHODS

2.1 Suit Description.

The Commander Brigade ensemble consisted of the suit and a separate outer garment. The suit was manufactured by MARMAC Manufacturing Company (McBee, SC) and was bright yellow-green in color. The style number of the ensemble was 10000F91 and the suit model number was 10KF91. Figure 1 is a digital photograph of the label found inside the suit. The outer garment was not to be tested and was stored elsewhere.

2.2 Swatch Preparation.

The day before testing was scheduled to begin, the suit was picked up from Mask Issue and transported to the laboratory. The suit was folded up for transport and was hung on a hanger once in the laboratory. The suit was stored this way during and after testing.

The swatch locations to be sampled were given in the PPE Test Team Work Contract for Level A Ensembles (written communication, R. Belmonte, Engineering Directorate, ERDEC, 25 June 1997). These swatch sampling locations were listed as suit material (SM), suit seam (SS), visor material (VM), zipper/suit material seam (ZP), glove (GL), and visor material/suit material seam (SV). The suit pass through could not be sampled, because it could not be made flat to fit in a permeation cell. The swatches were normally cut the day before testing and conditioned overnight at the test

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conditions. For a Monday test, swatches were cut Friday and conditioned over the weekend. Normally, the swatches would be laid in the environmental cabinet for conditioning.

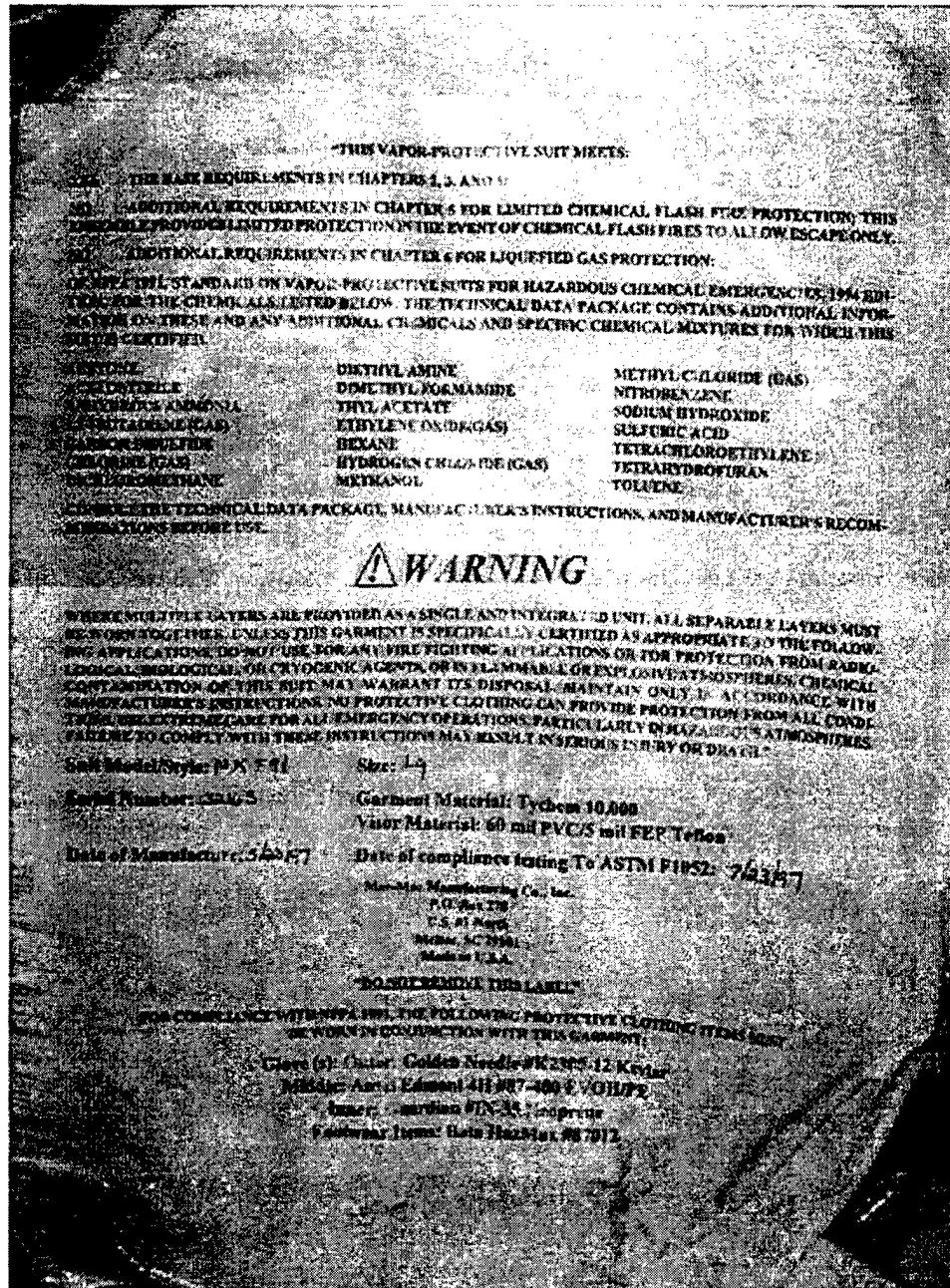


Figure 1. Commander Brigade Label

The swatches were numbered in accordance with the PPE Test Team Work Instructions (written communication, R. Belmonte, Engineering Directorate, ERDEC, 11 June 1997); for example LC-MAR-SM-01, etc. All swatches were cut in triplicate, one at a time on a sample press. The swatch diameter was 2 in.

The reference material was 80-mil silicone, using the M45 mask formulation, prepared by Malcolm Little of the M45 mask team. Preparation and conditioning were the same as for the suit swatches.

2.3

Test Procedure.

The procedure agreed upon by ERDEC and NRDEC was derived from the report entitled, "Permeation and Penetration Testing of Air Permeable, Semi-permeable and Impermeable Materials with Chemical Agents or Simulants (Swatch Testing)" dated 3 March 1997. The Modified Static Diffusion Procedure is found in Appendix A of this report. Subsequent to the agreement, ERDEC personnel determined that the usage of the 80-mil silicone did not meet the definition of a positive control. The silicone swatches were used as an indication of agent vapor permeation. Equipment and schedule limitations prevented the use of negative controls. The terminology of the test procedure was not modified to reflect these changes.

The TOP permeation cell was used and a digital photograph of one is given as Figure 2.

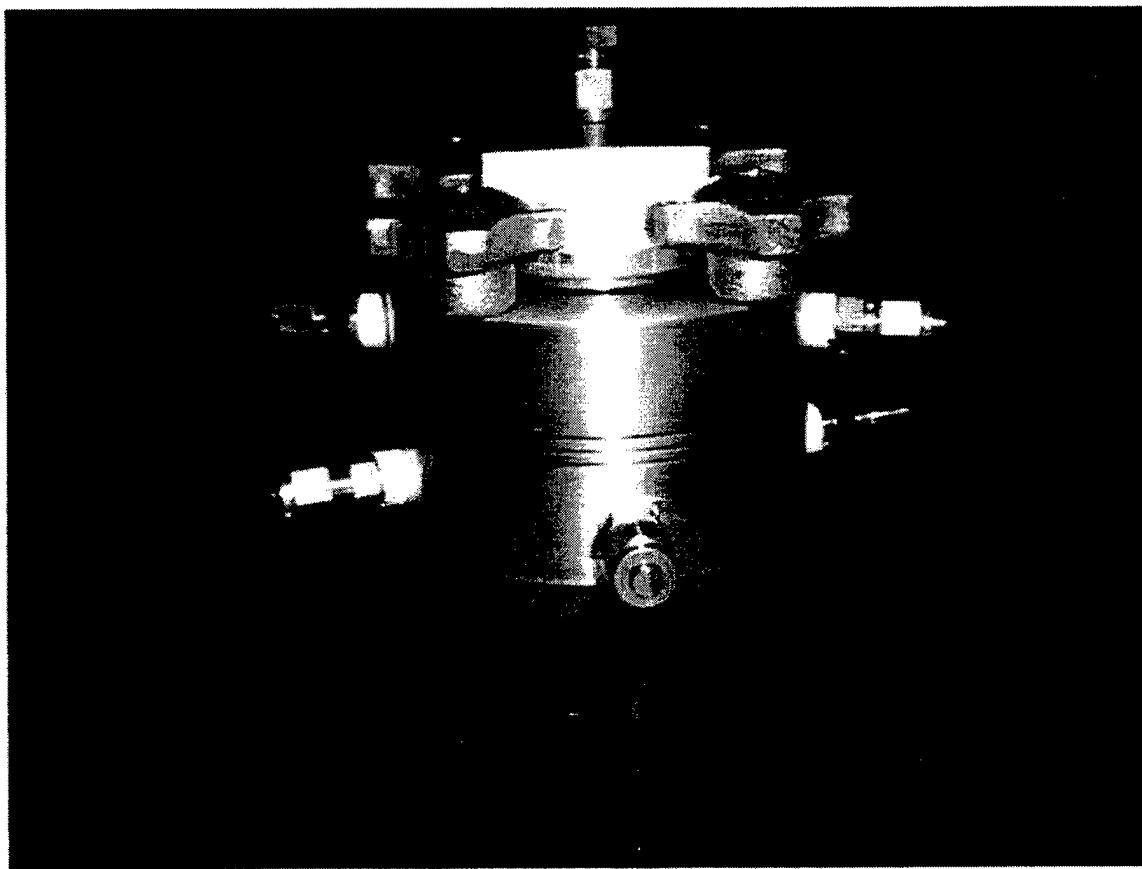


Figure 2. TOP Permeation Cell

The remainder of the test apparatus consisted of the following:

- Plastic environmental cabinet with sliding doors containing a permeation cell rack, circulating blower, and heat source (Figure 3).
- Flow/temperature/relative humidity control system; (Miller-Nelson Research Corporation, Monterey, CA) model HCS-410.
- Flow control system; (Tylan General Incorporated, Torrance, CA) Dynamass model FM-8.
- Mass flow controllers; (Tylan General Incorporated, Torrance, CA) model FC-260.
- Calibrated Vaisala humidity and temperature indicator.
- MINICAMS, serial number 1860, and Stream Selection System (CMS Research Corporation, Birmingham, AL), illustrated in Figure 4.

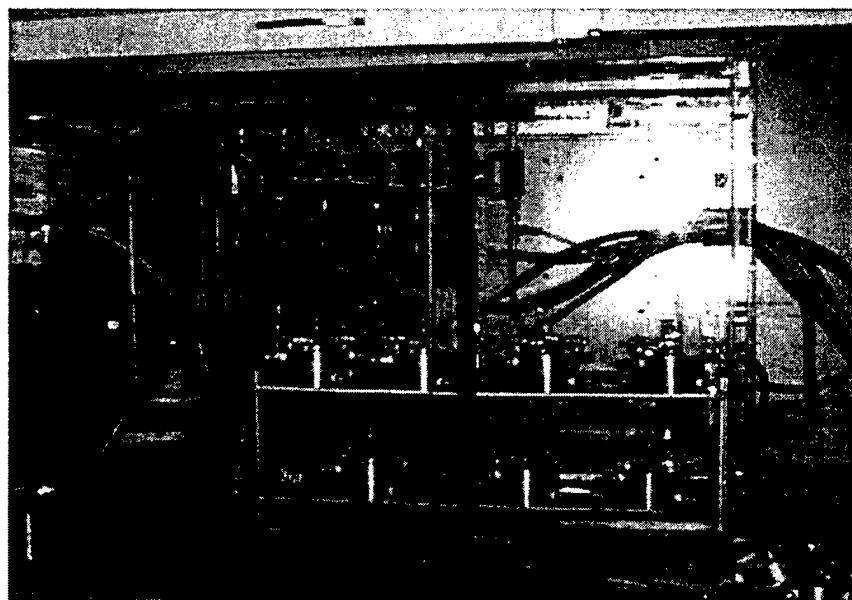


Figure 3. Environmental Cabinet

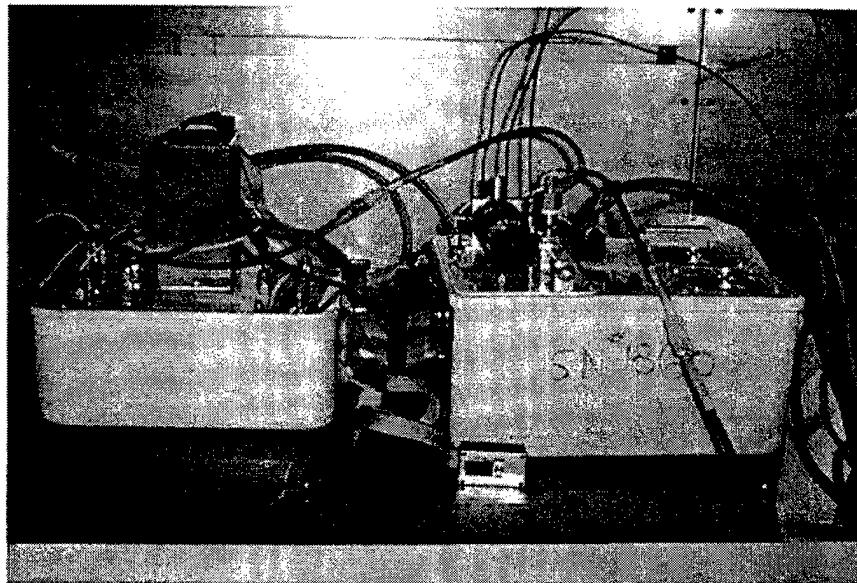


Figure 4. MINICAMS and Stream Selection System

3. RESULTS AND DISCUSSION

3.1 HD Results.

The HD permeation results are given in Appendix B as Tables B-1 through B-6. Average elapsed time was not used. The actual time that each swatch was sampled by the MINICAMS is shown.

The MINICAMS minimum detection limit was 1.0 ng for all test days. There were no visible effects on any of the materials from HD exposure. Cumulative permeation was highest for one zipper/material interface swatch (only slightly higher than for the suit material). Cumulative permeation was not elevated for any other swatches when compared to the suit material.

The average temperature was 95.0 °F, and 30.4% RH was the average for all tests. Test temperatures were greater than 90 °F due to a malfunction in the laboratory heating system, which caused the room temperature to be elevated, and the lack of a cooling capability in the test apparatus. The first MINICAMS cycle for each swatch was taken before agent was applied. This cycle served as an indication that no agent vapor was present prior to the start of the test. Negative control and positive control swatches were not used due to schedule and budget limitations.

3.2 GB Results.

The GB permeation results are given in Appendix C as Tables C-1 through C-8.

The MINICAMS minimum detection limit was 0.4 ng for all test days. There were no visible effects on any of the materials from GB exposure. Cumulative

permeation was highest for one visor/material interface swatch, one visor material swatch, and the zipper/material interface (over ten times higher than for the suit material). Most other swatches had cumulative penetrations that were similar to the suit material.

The average temperature was 91.4 °F, and 26.4% RH was the average for all tests. The first MINICAMS cycle for each swatch was taken before agent was applied. This cycle served as an indication that no agent vapor was present prior to the start of the test. Negative control and positive control swatches were not used due to schedule and budget limitations.

3.3 Material Thickness.

After the HD and GB testing was completed, thickness measurements of the suit material, visor material, and glove material were made. A swatch of material was cut from the suit immediately adjacent to the area from which the agent swatches were taken. Twenty-four thickness measurements were taken on each swatch using an Ames dial comparator (B. C. Ames Company, Waltham, MA). The average thickness of the suit material swatch was 0.035 in.; the visor material swatch was 0.066 in.; and the glove swatch was 0.038 in.

APPENDIX A
MODIFIED STATIC DIFFUSION PROCEDURE

MODIFIED STATIC DIFFUSION TEST

This test procedure was adapted from the "Semipermeable and Impermeable Materials Static Diffusion Penetration Testing (Liquid Agent Challenge/Vapor Penetration; delta p = 0, Single Flow Test) given in Test Operations Procedure (TOP) 8-2-501 dated 3 Mar 97.

The following procedure will be used:

Upon receipt of a suit, all available information concerning the suit will be recorded; date of manufacture, lot number, serial number, materials of construction, etc.

From each suit, 3 ea 1 and 15/16 in. diameter material swatches will be taken for HD and a like number taken for GB. Depending upon the suit configuration, three seam swatches (same diameter) will be taken plus triplicate swatches of other flat components such as other seams, visor, gloves, booties, etc. for HD and an equal number for GB. Each swatch will be placed in an airtight bag and given a unique serial number which will be placed on the bag. A list of serial numbers will be kept with the swatches.

The environmental chamber will be controlled at a temperature of 90 +/- 2 °F, and the maximum achievable RH without occurrence of condensation (70% +/- 10% RH). The temperature and RH readings will be checked weekly with a calibrated meter. The test cell air will be drawn from the chamber air. There will be no system control and data acquisition system. The temperature and RH will be recorded in a computer file. Flow rates will be manually recorded. There will be no differential pressure monitoring since differential pressure gages of sufficient sensitivity are not available.

The TOP test cell will be used. When assembling, the cell lugs will be tightened by hand to finger tight. The flow rate beneath each swatch will be 1 L/min which will be controlled by a linear mass flow controller. The flows will be checked with a calibrated test meter weekly. Each test cell will be checked for leaks after assembly by connecting it to the vacuum source and checking that the inlet flow is the same as the outlet flow on the mass flow controller (cell lugs will be retightened if flows don't match).

The samples will serve as their own negative controls while being preconditioned overnight by being MINICAMS monitored. Eighty mil silicone will be used as a positive control for each test (six suit swatches and one silicone swatch).

Agents GB and HD will be used. The contamination density will be 10 g/m² (eight each 1 µl HD droplets or ten each 1 µl GB droplets). A robotic agent application system is not available. The agent will be applied using the click/touch method with a Hamilton repeating dispenser.

Seven swatches will be tested at once. MINICAMS with stream selection system will monitor vapor penetration with a 3-min cycle. There will be three blank sampling intervals following the control. Each swatch will be sampled once every 30 min. The MINICAMS will be standardized weekly.

The test length will be 24 hr.

The test cells and o-rings will be aerated between uses. No other cleaning method will be used.

The data to be reported are cumulative penetration (ng/cm²) versus average elapsed time (minutes) for each swatch. The average elapsed time is the sum of the elapsed time for swatch 1 and the elapsed time for swatch 6 divided by 2. All recorded data will be placed in laboratory notebooks and a technical report will be drafted at the conclusion of this effort.

For entry into the DP database, the data for each swatch will be reported as cumulative penetration for the first four sampling intervals (approximately 12, 42, 72 ,and 102 min), and at approximately 6, 12, 18, and 24 hr.

APPENDIX B

HD TABLES

Table B-1. MARMAC Commander Brigade Suit Material vs. HD Liquid, 10 g/m²
Modified Static Diffusion Test, 12 Feb 98
Cumulative Penetration (ng/cm²)

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
1	0	3	0	6	2
30	0	33	0	36	24
60	0	63	0	66	49
90	0	93	0	96	75
120	2	123	0	126	105
150	8	153	2	156	135
180	15	183	7	186	166
210	23	213	13	216	196
240	31	243	18	246	226
270	39	273	23	276	256
300	47	303	29	306	285
330	55	333	34	336	312
360	62	363	39	366	339
390	69	393	44	396	366
420	76	423	48	426	391
450	83	453	53	456	415
480	89	483	57	486	437
510	95	513	61	516	460
540	101	543	65	546	482
570	107	573	69	576	504
600	112	603	71	606	525
630	117	633	71	636	546
660	122	663	71	666	567
690	127	693	71	696	588
720	132	723	71	726	608
750	134	753	71	756	628
780	137	783	71	786	647
810	139	813	71	816	667
840	139	843	71	846	687
870	139	873	71	876	706
900	139	903	71	906	726
930	139	933	71	936	745
960	139	963	71	966	764
990	139	993	71	996	784
1020	139	1023	71	1026	804
1050	139	1053	71	1056	823
1080	139	1083	71	1086	843
1110	139	1113	71	1116	862
1140	139	1143	71	1146	881
1170	139	1173	71	1176	900
1200	139	1203	71	1206	920
1230	139	1233	71	1236	940
1260	139	1263	71	1266	960
1290	139	1293	71	1296	981
1320	139	1323	71	1326	1001
1350	139	1353	71	1356	1022
1380	139	1383	71	1386	1043
1410	139	1413	71	1416	1065

Appendix B

Table B-2. MARMAC Commander Brigade Suit Seam vs. HD Liquid, 10 g/m²
Modified Static Diffusion Test, 12 Feb 98
Cumulative Penetration (ng/cm²)

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
9	0	12	0	15	0
39	0	42	0	45	0
69	0	72	0	75	0
99	0	102	0	105	0
129	2	132	0	135	0
159	7	162	0	165	0
189	13	192	0	195	0
219	18	222	2	225	0
249	24	252	6	255	0
279	30	282	10	285	0
309	36	312	12	315	0
339	41	342	12	345	0
369	46	372	12	375	0
399	51	402	12	405	0
429	57	432	12	435	0
459	62	462	12	465	0
489	66	492	12	495	0
519	71	522	12	525	0
549	75	552	12	555	0
579	80	582	12	585	0
609	84	612	12	615	0
639	88	642	12	645	0
669	92	672	12	675	0
699	97	702	12	705	0
729	99	732	12	735	0
759	99	762	12	765	0
789	99	792	12	795	0
819	99	822	12	825	0
849	99	852	12	855	0
879	99	882	12	885	0
909	99	912	12	915	0
939	99	942	12	945	0
969	99	972	12	975	0
999	99	1002	12	1005	0
1029	99	1032	12	1035	0
1059	99	1062	12	1065	0
1089	99	1092	12	1095	0
1119	99	1122	12	1125	0
1149	99	1152	12	1155	0
1179	99	1182	12	1185	0
1209	99	1212	12	1215	0
1239	99	1242	12	1245	0
1269	99	1272	12	1275	0
1299	99	1302	12	1305	0
1329	99	1332	12	1335	0
1359	99	1362	12	1365	0
1389	99	1392	12	1395	0
1419	99	1422	12	1425	0

Appendix B

**Table B-3. MARMAC Commander Brigade Glove Material vs. HD Liquid, 10 g/m²
Modified Static Diffusion Test, 17 Feb 98
Cumulative Penetration (ng/cm²)**

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
9	0	12	0	15	0
40	0	43	0	46	0
70	0	73	0	76	0
100	0	103	0	106	0
130	0	133	0	136	0
160	0	163	0	166	0
190	0	193	0	196	0
221	0	224	0	227	0
251	0	254	0	257	0
281	0	284	0	287	0
311	0	314	0	317	0
341	0	344	0	347	0
371	0	374	0	377	0
402	0	405	0	408	0
432	0	435	0	438	0
462	0	465	0	468	0
492	0	495	0	498	0
522	0	525	0	528	0
552	0	555	0	558	0
583	0	586	0	589	0
613	0	616	0	619	0
643	0	646	0	649	0
673	0	676	0	679	0
703	0	706	0	709	0
733	0	736	0	739	0
764	0	767	0	770	0
794	0	797	0	800	0
824	0	827	0	830	0
854	0	857	0	860	0
884	0	887	0	890	0
914	0	917	0	920	0
945	0	948	0	951	0
975	0	978	0	981	0
1005	0	1008	0	1011	0
1035	0	1038	0	1041	0
1065	0	1068	0	1071	0
1095	0	1098	0	1101	0
1126	0	1129	0	1132	0
1156	0	1159	0	1162	0
1186	0	1189	0	1192	0
1216	0	1219	0	1222	0
1246	2	1249	0	1252	0
1276	4	1279	0	1282	0
1307	5	1310	0	1313	0
1337	9	1340	0	1343	0
1367	13	1370	0	1373	0
1397	17	1400	0	1403	0
1427	20	1430	0	1433	0

Appendix B

Table B-4. MARMAC Commander Brigade Zipper/Material Interface vs. HD Liquid, 10 g/m²
 Modified Static Diffusion Test, 17 Feb 98
 Cumulative Penetration (ng/cm²)

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
0	0	3	1	6	0
31	0	34	10	37	0
61	0	64	19	67	0
91	0	94	29	97	0
121	0	124	39	127	0
151	0	154	51	157	0
181	2	184	63	187	0
212	7	215	76	218	0
242	13	245	91	248	2
272	21	275	110	278	6
302	31	305	134	308	10
332	47	335	164	338	15
362	74	365	199	368	19
393	115	396	241	399	25
423	169	426	292	429	30
453	235	456	348	459	36
483	308	486	409	489	42
513	387	516	475	519	48
543	472	546	544	549	54
574	563	577	615	580	60
604	658	607	690	610	67
634	759	637	770	640	74
664	866	667	852	670	81
694	977	697	936	700	88
724	1094	727	1023	730	96
755	1219	758	1113	761	104
785	1351	788	1207	791	112
815	1486	818	1303	821	120
845	1629	848	1403	851	128
875	1776	878	1506	881	137
905	1925	908	1611	911	145
936	2076	939	1719	942	155
966	2227	969	1828	972	164
996	2376	999	1939	1002	173
1026	2525	1029	2051	1032	182
1056	2672	1059	2165	1062	192
1086	2819	1089	2278	1092	201
1117	2967	1120	2393	1123	211
1147	3113	1150	2510	1153	220
1177	3255	1180	2628	1183	230
1207	3394	1210	2745	1213	239
1237	3534	1240	2864	1243	249
1267	3674	1270	2983	1273	259
1298	3812	1301	3107	1304	269
1328	3949	1331	3232	1334	279
1358	4087	1361	3357	1364	290
1388	4232	1391	3485	1394	300
1418	4378	1421	3615	1424	311

Appendix B

Table B-5. MARMAC Commander Brigade Visor Material vs. HD Liquid, 10 g/m²
Modified Static Diffusion Test, 19 Feb 98
Cumulative Penetration (ng/cm²)

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
3	0	6	0	9	1
33	0	36	0	39	3
63	0	66	0	69	3
93	0	96	0	99	5
123	0	126	0	129	9
154	2	157	0	160	14
184	6	187	0	190	19
214	11	217	0	220	24
244	16	247	0	250	29
274	21	277	0	280	34
304	26	307	0	310	39
335	31	338	0	341	45
365	35	368	0	371	50
395	40	398	0	401	55
425	45	428	0	431	60
455	49	458	0	461	64
485	53	488	0	491	69
516	57	519	0	522	74
546	61	549	0	552	78
576	63	579	0	582	82
606	63	609	0	612	87
636	63	639	0	642	91
666	63	669	0	672	95
697	63	700	0	703	97
727	63	730	0	733	97
757	63	760	0	763	97
787	63	790	0	793	97
817	63	820	0	823	97
847	63	850	0	853	97
878	63	881	0	884	97
908	63	911	0	914	97
938	63	941	0	944	97
968	63	971	0	974	97
998	63	1001	0	1004	97
1028	63	1031	0	1034	97
1059	63	1062	0	1065	97
1089	63	1092	0	1095	97
1119	63	1122	0	1125	97
1149	63	1152	0	1155	97
1179	63	1182	0	1185	97
1209	63	1212	0	1215	97
1240	63	1243	0	1246	97
1270	63	1273	0	1276	97
1300	63	1303	0	1306	97
1330	63	1333	0	1336	97
1360	63	1363	0	1366	97
1390	63	1393	0	1396	97
1421	63	1424	0	1427	97

Appendix B

Table B-6. MARMAC Commander Brigade Suit/Visor Interface vs. HD Liquid, 10 g/m²
Modified Static Diffusion Test, 19 Feb 98
Cumulative Penetration (ng/cm²)

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
12	1	15	0	18	2
42	3	45	0	48	9
72	3	75	0	78	14
102	3	105	0	108	21
132	5	135	0	138	27
163	9	166	0	169	34
193	13	196	0	199	40
223	18	226	0	229	47
253	22	256	0	259	54
283	27	286	0	289	61
313	31	316	0	319	68
344	36	347	0	350	74
374	40	377	0	380	81
404	44	407	0	410	87
434	49	437	0	440	94
464	53	467	0	470	100
494	57	497	0	500	106
525	59	528	0	531	111
555	59	558	0	561	117
585	59	588	0	591	122
615	59	618	0	621	128
645	59	648	0	651	133
675	59	678	0	681	138
706	59	709	0	712	143
736	59	739	0	742	147
766	59	769	0	772	152
796	59	799	0	802	157
826	59	829	0	832	161
856	59	859	0	862	166
887	59	890	0	893	170
917	59	920	0	923	174
947	59	950	0	953	179
977	59	980	0	983	183
1007	59	1010	0	1013	187
1037	59	1040	0	1043	191
1068	59	1071	0	1074	196
1098	59	1101	0	1104	200
1128	59	1131	0	1134	204
1158	59	1161	0	1164	208
1188	59	1191	0	1194	212
1218	59	1221	0	1224	217
1249	59	1252	0	1255	221
1279	59	1282	0	1285	226
1309	59	1312	0	1315	230
1339	59	1342	0	1345	235
1369	59	1372	0	1375	239
1399	59	1402	0	1405	244
1430	59	1433	0	1436	249

Appendix B

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APPENDIX C
GB TABLES

Table C-1. MARMAC Commander Brigade Suit Material vs. GB Liquid, 10 g/m²
Modified Static Diffusion Test, 25 Feb 98
Cumulative Penetration (ng/cm²)

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
1	0	4	0	7	0
32	15	35	16	38	19
62	67	65	69	68	74
92	142	95	144	98	145
122	215	125	215	128	214
152	281	155	276	158	273
182	338	185	316	188	313
213	379	216	339	219	336
243	408	246	362	249	358
273	432	276	381	279	377
303	454	306	398	309	394
333	474	336	414	339	409
363	492	366	429	369	423
394	510	397	444	400	436
424	527	427	457	430	449
454	544	457	471	460	462
484	559	487	483	490	474
514	574	517	495	520	485
544	589	547	507	550	496
575	604	578	518	581	507
605	617	608	529	611	517
635	630	638	539	641	527
665	644	668	549	671	536
695	656	698	559	701	545
725	668	728	568	731	554
756	679	759	577	762	563
786	691	789	587	792	572
816	702	819	596	822	581
846	712	849	604	852	589
876	723	879	613	882	597
906	733	909	621	912	605
937	743	940	630	943	612
967	753	970	638	973	620
997	762	1000	645	1003	627
1027	771	1030	653	1033	634
1057	781	1060	660	1063	641
1087	789	1090	668	1093	648
1118	798	1121	675	1124	654
1148	807	1151	682	1154	661
1178	815	1181	689	1184	667
1208	823	1211	696	1214	673
1238	830	1241	702	1244	679
1268	838	1271	708	1274	685
1299	846	1302	715	1305	692
1329	854	1332	722	1335	698
1359	861	1362	729	1365	704
1389	869	1392	736	1395	711
1419	880	1422	743	1425	717

Appendix C

Table C-2. MARMAC Commander Brigade Suit Seam vs. GB Liquid, 10 g/m²
Modified Static Diffusion Test, 25 Feb 98
Cumulative Penetration (ng/cm²)

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
10	0	13	0	17	0
41	23	44	27	47	29
71	84	74	90	77	97
101	159	104	163	107	172
131	228	134	231	137	240
161	287	164	290	167	299
191	321	194	327	198	339
222	339	225	348	228	363
252	361	255	370	258	385
282	380	285	389	288	405
312	396	315	404	318	421
342	411	345	419	348	437
372	425	375	432	379	452
403	439	406	445	409	466
433	452	436	458	439	480
463	464	466	469	469	493
493	476	496	481	499	506
523	488	526	492	529	519
553	499	556	503	560	530
584	510	587	513	590	542
614	520	617	523	620	553
644	530	647	533	650	564
674	540	677	542	680	574
704	549	707	551	710	584
734	558	737	560	741	594
765	568	768	569	771	604
795	577	798	578	801	614
825	586	828	586	831	624
855	594	858	594	861	633
885	602	888	602	891	642
915	611	918	610	922	651
946	619	949	617	952	660
976	626	979	625	982	669
1006	634	1009	632	1012	677
1036	641	1039	638	1042	686
1066	648	1069	645	1072	694
1096	655	1099	652	1103	701
1127	662	1130	659	1133	709
1157	669	1160	665	1163	716
1187	675	1190	671	1193	724
1217	682	1220	677	1223	731
1247	688	1250	683	1253	738
1277	694	1280	689	1284	746
1308	701	1311	696	1314	754
1338	708	1341	703	1344	761
1368	714	1371	709	1374	769
1398	721	1401	715	1404	776
1428	727	1431	721	1434	782

Appendix C

Table C-3. MARMAC Commander Brigade Glove Material vs. HD Liquid, 10 g/m²
 Modified Static Diffusion Test, 17 Feb 98
 Cumulative Penetration (ng/cm²)

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
9	0	12	0	15	0
40	0	43	0	46	0
70	0	73	0	76	0
100	0	103	0	106	0
130	0	133	0	136	0
160	0	163	0	166	0
190	0	193	0	196	0
221	0	224	0	227	0
251	0	254	0	257	0
281	0	284	0	287	0
311	0	314	0	317	0
341	0	344	0	347	0
371	0	374	0	377	0
402	0	405	0	408	0
432	0	435	0	438	0
462	0	465	0	468	0
492	0	495	0	498	0
522	0	525	0	528	0
552	0	555	0	558	0
583	0	586	0	589	0
613	0	616	0	619	0
643	0	646	0	649	0
673	0	676	0	679	0
703	0	706	0	709	0
733	0	736	0	739	0
764	0	767	0	770	0
794	0	797	0	800	0
824	0	827	0	830	0
854	0	857	0	860	0
884	0	887	0	890	0
914	0	917	0	920	0
945	0	948	0	951	0
975	0	978	0	981	0
1005	0	1008	0	1011	0
1035	0	1038	0	1041	0
1065	0	1068	0	1071	0
1095	0	1098	0	1101	0
1126	0	1129	0	1132	0
1156	0	1159	0	1162	0
1186	0	1189	0	1192	0
1216	0	1219	0	1222	0
1246	2	1249	0	1252	0
1276	4	1279	0	1282	0
1307	5	1310	0	1313	0
1337	9	1340	0	1343	0
1367	13	1370	0	1373	0
1397	17	1400	0	1403	0
1427	20	1430	0	1433	0

Appendix C

**Table C-4. MARMAC Commander Brigade Zipper/Material Interface vs. GB Liquid, 10 g/m²
Modified Static Diffusion Test, 26 Feb 98
Cumulative Penetration (ng/cm²)**

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
11	2	14	3	17	4
42	10	45	12	48	91
72	17	75	17	78	315
102	33	105	23	108	615
132	78	135	34	138	929
162	169	165	57	168	1247
192	328	195	96	198	1566
223	562	226	155	229	1879
253	839	256	237	259	2188
283	1129	286	342	289	2497
313	1424	316	470	319	2806
343	1723	346	621	349	3112
373	2026	376	791	379	3421
404	2332	407	979	410	3734
434	2640	437	1182	440	4050
464	2949	467	1397	470	4368
494	3258	497	1616	500	4696
524	3569	527	1837	530	5034
554	3882	557	2058	560	5364
585	4193	588	2279	591	5687
615	4504	618	2502	621	6018
645	4815	648	2728	651	6357
675	5126	678	2953	681	6698
705	5438	708	3180	711	7040
735	5750	738	3415	741	7383
766	6064	769	3655	772	7727
796	6381	799	3889	802	8069
826	6696	829	4122	832	8411
856	7012	859	4355	862	8752
886	7329	889	4589	892	9093
916	7645	919	4822	922	9435
947	7962	950	5055	953	9779
977	8277	980	5294	983	10122
1007	8591	1010	5535	1013	10465
1037	8909	1040	5770	1043	10807
1067	9227	1070	6000	1073	11147
1097	9545	1100	6228	1103	11489
1128	9863	1131	6457	1134	11831
1158	10180	1161	6683	1164	12173
1188	10496	1191	6900	1194	12514
1218	10811	1221	7113	1224	12852
1248	11124	1251	7327	1254	13187
1278	11436	1281	7538	1284	13519
1309	11743	1312	7744	1315	13849
1339	12048	1342	7952	1345	14177
1369	12353	1372	8164		

Appendix C

Table C-5. MARMAC Commander Brigade Visor Material vs. GB Liquid, 10 g/m²
Modified Static Diffusion Test, 24 Feb 98
Cumulative Penetration (ng/cm²)

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
11	0	14	3	17	0
41	8	45	12	47	10
71	30	75	17	77	29
101	62	105	23	107	47
131	100	135	34	137	66
161	141	165	57	167	85
191	182	195	96	197	104
221	223	226	155	227	121
251	263	256	237	257	139
281	300	286	342	287	153
311	334	316	470	317	164
341	367	346	621	347	174
371	401	376	791	377	187
401	436	407	979	407	202
431	471	437	1182	437	216
461	505	467	1397	467	231
491	539	497	1616	497	244
521	571	527	1837	527	258
551	603	557	2058	557	270
581	633	588	2279	587	283
611	663	618	2502	617	295
641	692	648	2728	647	306
671	720	678	2953	677	316
701	747	708	3180	707	327
731	774	738	3415	737	337
761	800	769	3655	767	347
791	825	799	3889	797	357
821	850	829	4122	827	367
851	874	859	4355	857	376
881	897	889	4589	887	385
911	920	919	4822	917	394
941	943	950	5055	947	402
971	966	980	5294	977	411
1001	987	1010	5535	1007	419
1032	1009	1040	5770	1038	427
1062	1030	1070	6000	1068	435
1092	1050	1100	6228	1098	443
1122	1070	1131	6457	1128	451
1152	1090	1161	6683	1158	458
1182	1109	1191	6900	1188	465
1213	1128	1221	7113	1219	472
1243	1147	1251	7327	1249	479
1273	1166	1281	7538	1279	485
1303	1183	1312	7744	1309	492
1333	1201	1342	7952	1339	498
1363	1219	1372	8164	1369	504
1394	1236			1400	510
1424	1253			1430	516

Appendix C

Table C-6. MARMAC Commander Brigade Suit/Visor Interface vs. GB Liquid, 10 g/m²
 Modified Static Diffusion Test, 24 Feb 98
 Cumulative Penetration (ng/cm²)

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
2	0	5	0	8	0
32	4	35	10	38	32
62	16	65	39	68	141
92	34	95	85	98	325
122	54	125	142	128	567
152	74	155	202	158	840
182	93	185	264	188	1130
212	111	215	327	218	1424
242	129	245	389	248	1715
272	144	275	449	278	2007
302	156	305	507	308	2291
332	167	335	561	338	2562
362	180	365	615	368	2826
392	195	395	671	398	3087
422	209	425	725	428	3349
452	224	455	779	458	3602
482	239	485	832	488	3848
512	253	515	883	518	4086
542	266	545	933	548	4317
572	279	575	981	578	4545
602	292	605	1027	608	4764
632	304	635	1072	638	4973
662	315	665	1116	668	5172
692	326	695	1158	698	5366
722	336	725	1199	728	5554
752	347	755	1240	758	5734
782	356	785	1279	788	5910
812	366	815	1317	818	6079
842	376	845	1355	848	6249
872	385	875	1392	878	6417
902	394	905	1428	908	6579
932	403	935	1464	938	6739
962	412	965	1500	968	6898
992	420	995	1534	998	7049
1023	429	1026	1568	1029	7197
1053	437	1056	1602	1059	7339
1083	444	1086	1634	1089	7479
1113	452	1116	1666	1119	7619
1143	460	1146	1698	1149	7756
1173	468	1176	1729	1179	7889
1204	475	1207	1760	1210	8020
1234	482	1237	1789	1240	8147
1264	489	1267	1819	1270	8271
1294	496	1297	1848	1300	8395
1324	503	1327	1877	1330	8519
1354	509	1357	1905	1360	8640
1385	515	1388	1932	1391	8757
1415	521	1418	1958	1421	8872

Appendix C